A Numerical Study on Water Mist Suppresion of Methane-Air Diffusion Flames.

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The use of water mist for fire suppresion has been an active area of research and development in recent years. The need for low weight impact replacement sprinkler systems on commerical ships has been driven by International Maritime Organization (IMO) regulations requiring retrofit of fire suppression systems on most commerical marine vessels. This gave immediate impetus to the development of low water demands, high efficiency mist systems to replace sprinkler systems. The phaseout of halons and the search for alternative technologies that preserve most of the benefits of a clean total flooding agent without adverse environmental impact has sparked recent interests in water mist technology.

Fine water mist relies on relatively small droplet sprays to extinguish fires. The mechanisms of extinguishment include gas phase cooling (evaporation and heat capacity), oxygen displacement by steam, wetting of fuel surfaces, and attenuation by radiative heat transfer. Although the potential efficacy of water mist fire suppresion systems has been demonstrated in a wide range of applications and by numerous experimental programs, the underlying physical processes involved in the suppression and their relative impact have not been clearly understood. Factors that contribute to the success or failure of a water mist system for a particular application include droplet size, velocity, the spray pattern geometry as well as the momentum and mixing characteristics of the spray jet. At this time, the effect of these factors on fire suppresion and system effectiveness is not well known.

A numerical model has been developed to obtain a detailed understanding of the various physical and chemical processes involved during the combustion of methane air diffusion flames stabilized above a Wolfhard-Parker burner and the inhibition of these flames by water sprays. The conservative form of the full compressible Navier-Stokes equations for a multi-component chemically reacting fluid flow are solved. Chemical reactions are described by a single step finite rate arrhenius kinetics or a flame sheet model. A real gas thermodynamic model is employed and allowances are made for variable transport properties. For a detailed understanding of the process of spray vaporization, it is necessary to have knowledge of the mechanism of vaporization of the individual droplets and the size and spatial distribution of the droplets that make up the spray. A hybrid Eulerian-Lagrangian sectional approach is used to analyze spray vaporization. The method is based on dividing the droplet size domain into sections and dealing only with one integral quantity in each section such as surface area or total volume. The advantage of this approach is that the integral quantity is conserved within the computational domain and the number of conservation equations is substantially reduced to be equal to the number of sections.

Numerical simulations have been performed to obtain detailed structure of the temperature contours obtained above a methane air diffusion flame burner and have been found to compare favourably with experimental results. Parametric studies on the effect of nitrogen dilution have been completed and are compared with experimental results. Detailed simulation have been performed to investigate the effect of 100 million water droplets (150 micron diameter) introduced as a co-flow in the air stream. Figures a and b show the temperature profiles obtained above a methane air diffusion flame burner with and without water droplets. Simulations have been performed to compute the relative importance of gas phase thermodynamic cooling and oxygen displacement. The fraction of water droplets that interacts with the flame sheet (based on streamline profiles) are computed for various initial droplet diameters. The presentation will attempt to quantify the effect of water droplet size, droplet number density and velocity of the jet spray on methane air diffusion flames.

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Effect of Water Mist Suppresion on Methane Air Diffusion Flames